Chapter 6.5 Working Safely with Cryogenic Fluids

This could be you . . .

Two technicians passed out while transferring liquid nitrogen from a truck because nitrogen spilled into the loading dock and displaced oxygen in the area. They were rescued and are okay.

A liquid helium dewar ruptured. Fortunately, no one was in the room at the time.

A liquid nitrogen dewar exploded and sent glass fragments flying. Fortunately, the technicians working with the dewar were not in the path of the flying glass.

6.5.1 Applicability of this chapter

6.5.1.1 You are required to follow this chapter if you:

a. Use, handle, store, or transfer cryogenic fluids as a part of your job.

b. Supervise anyone who does the above tasks.

6.5.2 What this chapter covers

This chapter covers the minimum requirements to handle and use common cryogenic fluids safely.

6.5.3 Definition of a cryogenic fluid

6.5.3.1 A cryogenic fluid is a liquid with a normal boiling point below –238°F (221°R, –150°C, 123 K). Commonly used cryogenic fluids include the following:

a. Liquid helium (LHe) – normal boiling point –452°F

b. Liquid hydrogen (LH_2) – normal boiling point –423°F

c. Liquid nitrogen (LN_2) – normal boiling point –320°F

d. Liquid oxygen (LO_2) – normal boiling point –297°F

e. Liquid air (Lair) – normal boiling point –318°F

f. Liquid argon (LAr) – normal boiling point –303°F

NOTE: Fluorine, neon, carbon monoxide, methane, nitric oxide, and krypton can be liquefied and are cryogenic fluids, but are rarely used at JSC in the liquid state.

6.5.4 Hazards of cryogenic fluids

6.5.4.1 Cryogenic fluids could cause any of the following safety problems:

a. Cryogenic burns from the extreme cold, eye damage from cold vapors.

b. Skin stuck to cold surfaces.

c. Over-pressurization and rupture of a pressure system or vessel—when cryogenic fluids try to vaporize due to heating from the surroundings, they can increase the pressure 700 to 1,000 times.

d. Asphyxiation.

e. Upper respiratory irritation from breathing cold vapors.

f. Fire and explosion.

g. Leaks, sprays, or spills contacting nearby equipment and causing structural failures due to excessive thermal stresses within the materials.

6.5.5 Precautions to observe when working with any cryogenic fluids

6.5.5.1 If you handle any cryogenic fluids, you shall observe these precautions:

a. Do tasks involving cryogenic fluids with two or more people, except for laboratory use from a small close container.

b. Deactivate systems with proper energy controls found in Chapter 8.2, “Lockout/tagout Practices,” of this Handbook before you start any maintenance or repair work.

c. Vent cryogenic systems through appropriate valves. Release gases so that the wind or room ventilation will direct them away from people.

d. If you need to put warm objects in cryogenic fluids, do it slowly and use tongs to insert or remove the objects.

e. If you need to put a cryogenic fluid into a warm container, do it slowly to minimize boiling, splashing, and thermal stresses.

f. Keep unprotected body parts away from the cold surfaces of pipes or vessels that contain cryogenic fluids.

g. Leave frost that forms on un-insulated surfaces undisturbed to help prevent Lair (LN_2 plus LO_2) from accumulating.

h. Do a written hazard analysis for any area where cryogenic fluids are used or stored.

i. Make sure you have a procedure or hazardous operations permit as described in Chapter 5.8, “Hazardous Operations: Safe Practices and Certification,” of this Handbook.

j. Ensure that all personnel involved are trained in the safe handling of cryogenic fluids.

6.5.6 Locations for working with cryogenic fluids

6.5.6.1 Any work that you do with cryogenic fluids shall be:

a. Near safety and firefighting equipment that you properly maintain.

b. Away from combustibles.

c. Away from unprotected or unauthorized personnel.

d. In well-ventilated areas. Use oxygen analyzers and alarms to monitor for low oxygen concentrations, as required by the hazard analysis, if you are working with LHe, LH_2, LN_2, or LAr. Use oxygen analyzers and alarms to monitor for high oxygen concentrations if you are working with LO_2.

6.5.7 Storing cryogenic fluids

6.5.7.1 Locations where cryogenic fluids are stored shall follow these requirements:

a. Store cryogenic fluids outside or in large, open, and well-ventilated rooms that are vented to the outside. Use oxygen analyzers and alarms as described in subparagraph 6.5.6.1.d above.

b. Continuously ventilate any area where inert cryogenic fluids are used, even at night and on weekends, unless you remove them from the area. Leave air handlers or exhaust ventilation on at all times.

c. Label the entrance to any area with inert cryogenic fluids to alert personnel that asphyxiation is possible in that area due to oxygen-displacing cryogenics.

d. If you store LH_2 inside, make sure to vent any gas that escapes either to the outside or to a safe location. If you vent the gas through ductwork, the ductwork shall be independent of other systems and contain no ignition sources.

e. You shall use hydrogen detectors (either permanently installed or portable) wherever you use hydrogen.

f. Within 3 feet of hydrogen sources (such as where connections are regularly made and disconnected), you shall use Class I, Division 1, Group B electrical equipment as described in National Fire Protection Association Standard 70, “National Electric Code.”

g. Between 3 and 25 feet of hydrogen sources, you shall use Class I, Division 2, Group B electrical equipment.

6.5.8 Action to take in case of a skin burn from a cryogenic fluid

If you spill any cryogenic fluid on yourself, seek immediate medical attention or call x33333 or (281) 483-3333. If there are no further injuries, rinse off in a safety shower with tepid (60° - 100°F) water.

6.5.9 Precautions for storing, using, or transferring cryogenic fluids

6.5.9.1 If you transfer, use, or store any cryogenic fluids, you shall observe these precautions:

a. Transfer liquid slowly to reduce thermal shock to containers.

b. Don't breathe cryogenic vapors.

c. Don't allow ice to accumulate on a neck of or near the vent of a cryogenic vessel. Ice could plug the vent and cause the vessel to rupture.

d. Empty and purge any cryogenic vessel with ice accumulating on the outer surface and either dispose of it or take it out of service for repair. The ice indicates a poor vacuum in the annular space, resulting in poor insulation.

e. Tape or cage exposed portions of glass containers to minimize flying glass if the glass breaks.

f. Follow these requirements to prevent sparks or arcs:

   (1) Ground all stationary hydrogen and oxygen equipment.

   (2) Bond mobile and stationary equipment used to transfer and receive Lair, LO_2, and LH_2 and make sure that all equipment involved in the transfer shares a common ground.

   (3) Purge all condensable gases from LH_2 transfer hoses in service with helium gas. Transfer LH_2 only with specially designed equipment.

6.5.10 Precautions for handling LN_2

6.5.10.1 As a gas, nitrogen is colorless, odorless, tasteless, nontoxic, and almost totally inert, as described in Attachment 6.5D, Appendix F. The main health hazard of nitrogen is asphyxiation. Nitrogen can displace oxygen in the air in enclosed or semi-enclosed areas. If you use or handle LN_2, you shall observe these precautions:

a. Don't enter a tank, sump, or closed space that has contained LN_2 until you have purged the space and stabilized the oxygen concentration at normal levels. Air testing is required to document that oxygen concentration is at a safe level. To enter an oxygen-deficient space:

   (1) You shall wear an air-supplying breathing apparatus.

   (2) The Safety and Test Operations Division and the Occupational Health Branch shall approve the entry. An approved confined space entry procedure and permit may also be required (see Chapter 6.10).

   (3) If it is necessary to enter, specially trained rescue personnel shall stand by to rescue entry personnel immediately during an emergency.

b. Isolate the LN_2 source using a minimum of two positive blocks, such as valves, between the source and the system or equipment. The Safety and Test Operations Division shall approve any other arrangement.

c. If you use valves to block a system, chain or lock them to prevent accidental opening and tag them with DO NOT OPERATE tags. See Chapter 8.2 of this Handbook for detailed requirements on lockout/tagout.

d. If you use an open bleed valve to prevent nitrogen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.

e. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

6.5.11 Precautions for handling LO_2

6.5.11.1 Oxygen is nonflammable but vigorously supports and accelerates combustion as described in Attachment 6.5B, Appendix F. Many substances will burn or explode more easily in an oxygen-enriched atmosphere. If you handle LO_2, you shall follow these precautions to avoid fires or explosions:

a. Wear impermeable clothing. Oxygen can saturate clothing, rendering it extremely flammable. Clothing described as flame resistant or flame retardant in air may be flammable in an oxygen-enriched atmosphere. Impermeable clothing with good insulating properties is effective in protecting the wearer from burns due to cryogenic splashes or spills, but even these components can absorb oxygen.

b. Don't allow any organic materials or flammable substances to come in contact with LO_2 or oxygen-enriched atmospheres. Some of the organic materials that can react violently with oxygen are oil, grease, asphalt, kerosene, cloth, tar, and dirt containing oil or grease.

c. Open and close valves in LO_2 systems slowly.

d. If your clothing is soaked or splashed with LO_2 or oxygen vapors, and there are no further injuries, move to a safety shower and rinse with tepid (60° - 100°F) water. Remove clothing that is not adhered to the skin and place it in a well-ventilated area away from flammable and combustible materials for at least 30 minutes.

e. Avoid or leave any area exposed to an oxygen-enriched atmosphere. Avoid all sources of ignition.

f. Don't do welding, cutting, or spark-producing operations within 100 feet of LO_2 storage units or pipes without monitoring the oxygen levels with an oxygen analyzer. Don't do these operations if the work area atmosphere is oxygen-enriched. You may monitor oxygen levels intermittently or continuously at the discretion of the Safety and Test Operations Division or the supervisor.

g. Don't smoke around oxygen systems. Post NO SMOKING signs around oxygen systems. Don't smoke for at least 30 minutes after exposure to LO_2; oxygen tends to cling to your clothing.

h. Keep a fire extinguisher available wherever an exposure to LO_2 can occur.

(1) If most of the material that could be exposed to the LO_2 is paper or wood (Class A fuel), keep a 2½-gallon water-filled fire extinguisher within 75 feet. Dry chemical extinguishers are ineffective against this type of fire.

(2) If most of the material that could be exposed to the LO_2 is oil or grease (Class B fuel), keep a 10-pound dry chemical (60-B:C) or multipurpose (4-A:60-B:C) extinguisher within 50 feet.

i. Don't enter a tank, sump, or closed space that has contained LO_2 until you have purged the space and stabilized the oxygen concentration levels. Air testing is required to confirm that the atmosphere is neither oxygen deficient nor oxygen enriched. The Safety and Test Operations Division shall approve any space with an oxygen-enriched atmosphere. An approved confined space entry procedure and permit may be required.

j. Isolate the LO_2 source by using a minimum of two positive blocks, such as valves, between the source and the system or equipment. The Safety and Test Operations Division and Occupational Health Branch shall approve any other arrangement.

k. If you use valves to block a system, chain or lock them to prevent accidental opening, and tag them with DO NOT OPERATE tags. See Chapter 8.2 of this Handbook for detailed requirements on lockout/tagout.

l. If you use an open bleed valve to prevent oxygen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.

m. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

6.5.12 Precautions for handling LH_2

6.5.12.1 LH_2 vaporizes rapidly, is very flammable, and burns with an invisible flame as described in Attachment 6.5C, Appendix F. Gaseous hydrogen can be "self-igniting" when released under high pressure. At ordinary temperatures, hydrogen is very light. However, LH_2 vapors are slightly heavier than 70°F air and can spread along the ground for considerable distances. If you handle LH_2, you shall observe these precautions to avoid a fire or explosion:

a. Keep combustible materials away from hydrogen.

b. Don't do welding, cutting, or spark-producing operations within 100 feet of hydrogen storage units, flare stacks, vent lines, or pipes. Use a hydrogen detector to make sure there is no hydrogen in the area.

c. Don't do any welding, cutting, or spark-producing operations on components of a LH_2 system until you drain them and purge them with an inert gas.

d. Don't enter a tank, sump, or closed space that has contained LH_2 until you have purged the space and stabilized the oxygen concentration at normal levels. Air testing is required to determine that the oxygen atmosphere is within safe levels. The Safety and Test Operations Division and Occupational Health Branch shall approve any entry into a space with a flammable or oxygen-deficient atmosphere. See paragraph 6.5.10.1.a. for restrictions on entry into a contaminated space. An approved confined space entry procedure and permit may be required (see Chapter 6.10).

e. Isolate the LH_2 source by using a minimum of two positive blocks, such as valves, between the source and the system or equipment. Make sure the line section between the valves has a safety relief device or bleed valve. The Safety and Test Operations Division shall approve any other arrangement.

f. If you use valves to block a system, chain or lock them to prevent accidental opening and tag them with DO NOT OPERATE tags. See Chapter 8.2 of this Handbook for detailed requirements on lockout/tagout.

g. If you use an open bleed valve to prevent hydrogen pressurization, chain or lock it open to prevent pressure buildup between blocks or flanges and vent it to outside the work area.

h. Use blank or blind flanges as necessary. If the system contains no bleed valves, install a bleed valve on each flange.

i. Keep a 10-pound multipurpose (4-A:60-B:C) or a 10-pound CO_2 (10-B:C) fire extinguisher within 50 feet of potential fuel sources.

6.5.13 Actions to take for an LO_2 spill or fire

a. Keep all ignition sources, equipment, and people away from LO_2 spills for at least 30 minutes after all frost or fog has disappeared. The spill area surfaces, especially asphalt, could ignite from friction or shock.

b. Attempt to extinguish an LO_2 fire with hand fire extinguishers immediately because many materials burn rapidly in LO_2. Then quickly evacuate the area in an orderly manner.

6.5.14 Actions to take for an LH_2 spill or fire

a. Shut off the hydrogen flow as soon as possible, and especially before attempting to extinguish a hydrogen fire.

b. Remember that hydrogen burns with an invisible flame.

c. If no hydrogen flame detector is available, use a long piece of wood or other combustible material to probe for flames before approaching the area of the spill.

d. Spray water on the spill to prevent a fire.

e. Spray large quantities of water on adjacent equipment to cool the equipment.

f. Attempt to extinguish only small fires.

6.5.15 Special precautions for handling other cryogenic fluids

If you use any cryogenic fluids not mentioned above, contact the Safety and Test Operations Division for additional safety requirements. Other cryogenic fluids may include LAr or LHe.

6.5.16 Protective clothing and equipment to use when handling cryogenic fluids

6.5.16.1 When you work with cryogenic fluids, you shall wear the protective equipment that is appropriate for the hazards of the task you are doing. The following list includes common protective equipment for working with cryogenic fluids:

a. Eye protection

b. Face shields

c. Insulated gloves with gauntlets—the gloves should be loose fitting

d. Cuff-less trousers outside of boots or work shoes; don't wear tennis shoes or open-toed shoes

e. Coveralls or smocks, with long sleeves, approved for use with the cryogen you are using

NOTE: See Chapter 5.6, "Personal Protective Equipment," of this Handbook for more requirements on protective equipment.

6.5.17 Training to work with cryogenic fluids

6.5.17.1 You need to be certified to handle cryogenic fluids as described in Chapter 5.8 of this Handbook. Your training shall cover the following subjects for each cryogenic material you work with:

a. Nature and properties of the cryogenic fluid in both liquid and gaseous states.

b. Correct PPE to use in specific environments and where you can find it.

c. Approved materials that are compatible with the cryogenic fluid.

d. Proper use and care of protective clothing and equipment.

e. First-aid procedures.

f. Emergency procedures for handling situations such as leaks, spills, and fires.

g. Good housekeeping practices.

6.5.18 Design requirements for cryogenic areas and systems

6.5.18.1 In addition to the standards listed in paragraph 6.5.19 below, systems handling cryogenic fluids shall meet these requirements:

a. Insulate cryogenic vessels and lines or provide drip pans under exposed pipes.

b. Insulate cryogenic containers.

c. Provide frangible (burst) discs or other pressure-relief devices between the inner vessels and outer tank shell so that pressure rupture cannot occur.

d. Provide frangible (burst) discs or other pressure-relief devices between sections of a cryogenic fluid system that may trap LO_2, such as between two valves.

e. Provide enough continuous ventilation and hazardous gas monitors where accidental releases or spills could occur, as indicated by the hazard analysis.

6.5.19 Other requirements to follow while handling cryogenic fluids

In addition to the requirements in this chapter, you shall follow these standards as they apply to the work you do. Chapter numbers are for chapters in this Handbook.

For . . .	*Follow this standard . . .*
Working with cryogenic fluids	29 CFR 1910.103 and 29 CFR 1910.104
Certifying employees to work with cryogenic liquids	Chapter 5.8 of this Handbook

For . . .	*Follow this standard . . .*
Designing cryogenic systems	• JPR 1710.13, “Design, Inspection, and Certification of Pressure Vessels and Pressurized Systems,” (current version) • NFPA 55, “Compressed Gases and Cryogenic Fluids Code”, 59A, “Liquefied Natural Gas,” and others, as applicable
Finding more data on cryogenic fluids	Attachments 6.5A – 6.5D, Appendix F
Finding requirements for electrical equipment you can use in areas with hydrogen	NFPA 70